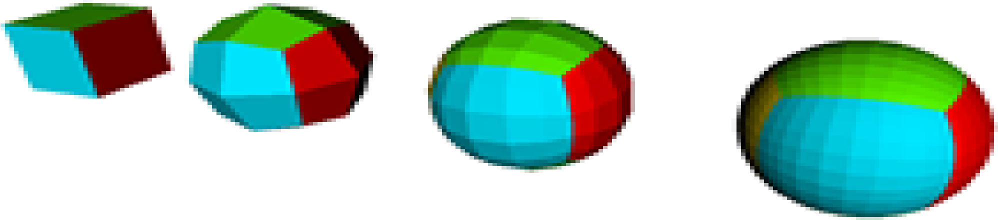
Implementation of the GRIDSPEC extensions into LibCF



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With contributions from

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Steve Hankin and Ansley Manke (PMEL) – CF, Ferret

Jonathan Gregory (UK Met Office) – CF

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CF conventions (1.5) want all the data stored in a single NetCDF file

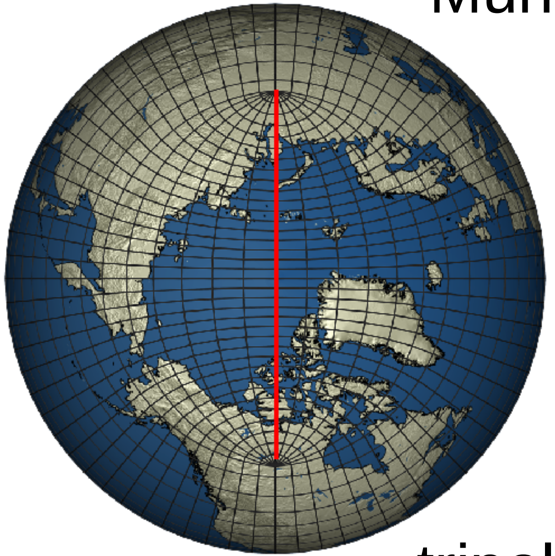
- Mainly designed to cover longitude-latitude grids
- Each variable (field) has assigned attributes such as
  - standard_name, e.g. “air_temperature”
  - units, e.g. “K”
  - [coordinates, e.g. “lat lon”]
- Grid and data live in the same file
- Current CF conventions don't scale to hi-res
  - 500 years, daily, 1degx1deg require O(1-100TB)
  - 1-100 days to transfer over the wire
- CF 1.5 doesn't play well with:
  - Time aggregated data (could use union aggregation in NcML)
  - Data distributed over multiple grids (e.g. mosaics)

http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.5/cf-conventions.html

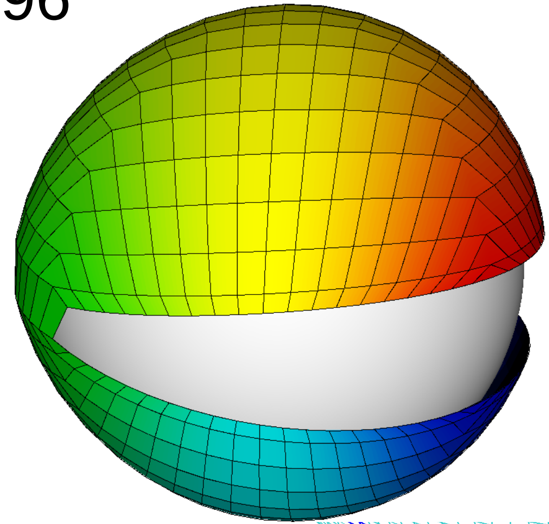
Mosaics form a new class of grids

- Addressing the need to avoid poles
  - Problems of numerical stability (Courant condition violated when using explicit time stepping. May need to apply filtering techniques to damp oscillations at the poles.
  - “Over”-resolution near the poles (waste of resources)

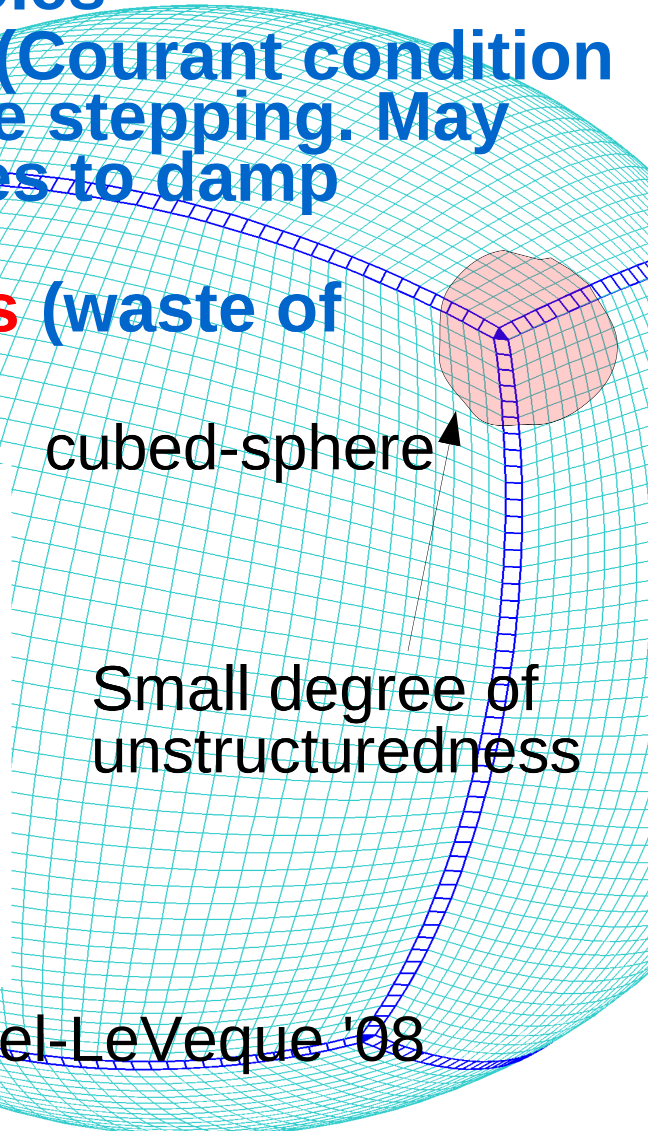
Murray '96



tripolar



Calhoun-Helzel-LeVeque '08

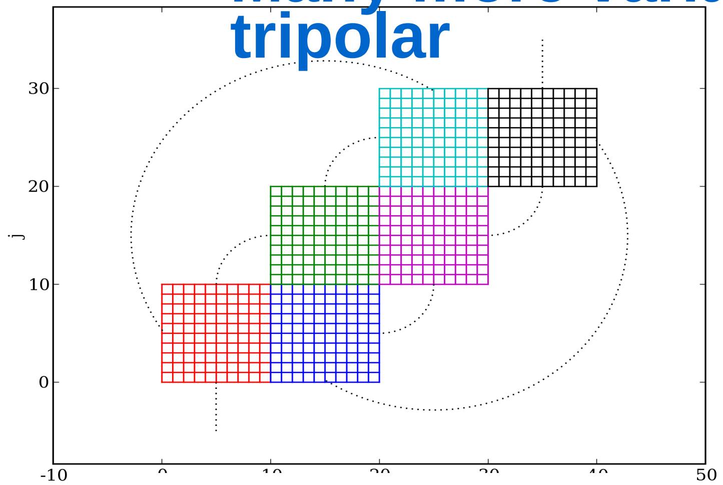


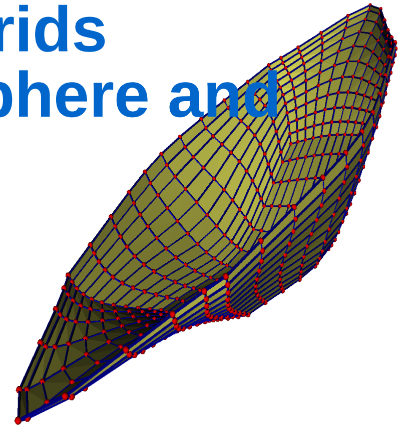
cubed-sphere

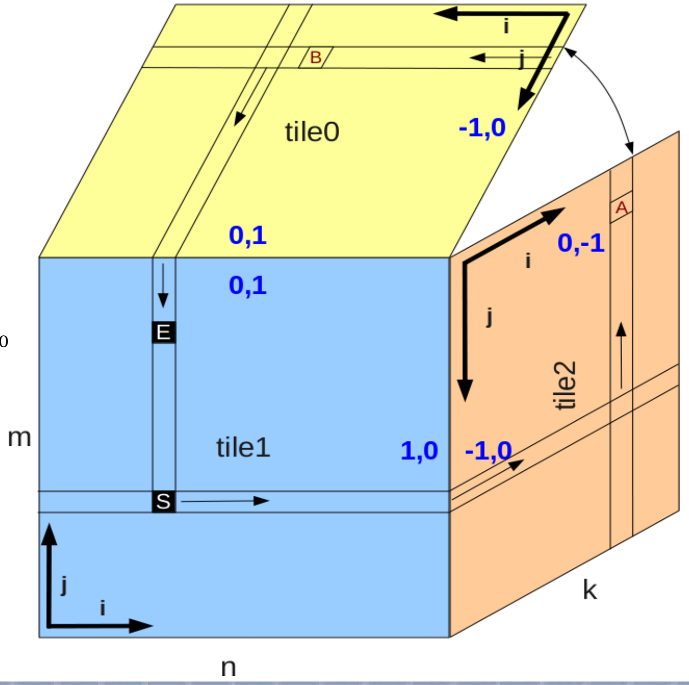
Small degree of unstructuredness

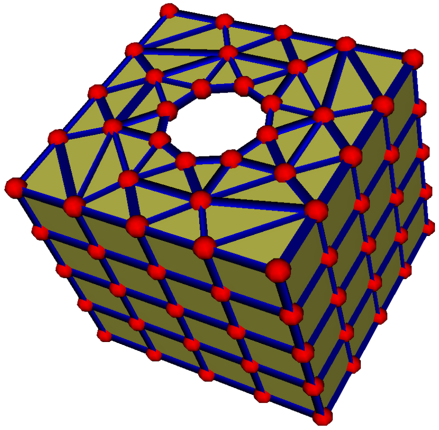
Mosaics (tripolar, cubed-sphere, ...) are <u>unstructured</u> assemblies of (typically) <u>structured</u> grids

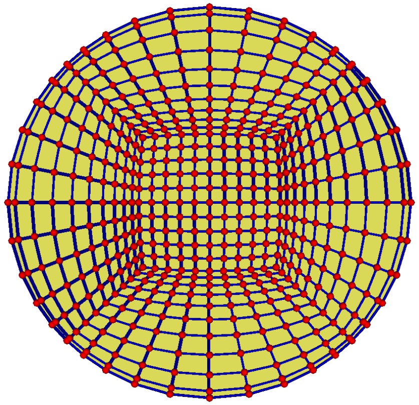
- Each tile is a curvilinear grid
- Complex folding between tiles in index space
- Unstructured assembly of structured grids
- Many more variations beyond cubed-sphere and tripolar





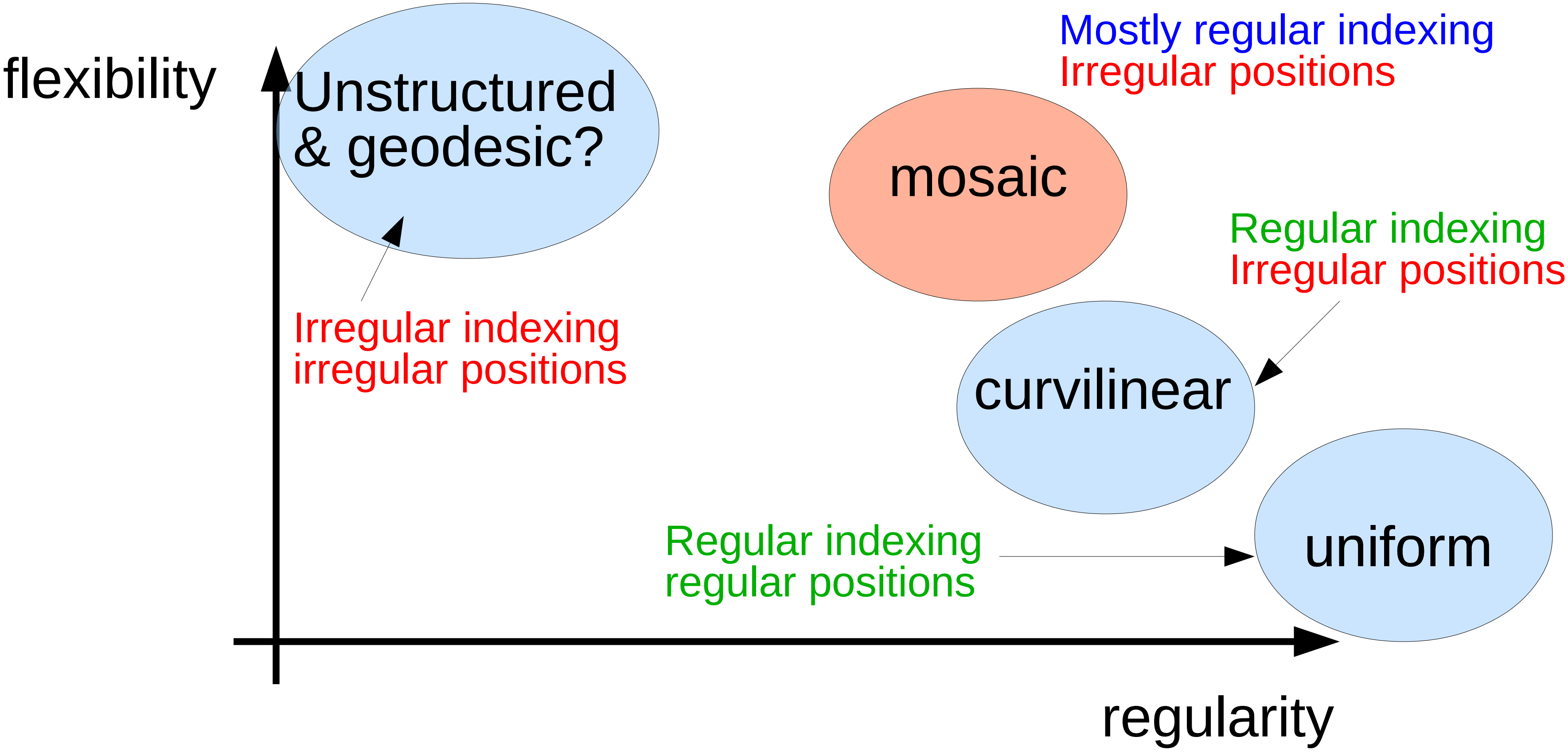






Mosaics add flexibility to structured grids

- Without paying the cost of unstructured grids



flexibility

Unstructured & geodesic?

Irregular indexing irregular positions

Mostly regular indexing Irregular positions

mosaic

Regular indexing Irregular positions

curvilinear

Regular indexing regular positions

uniform

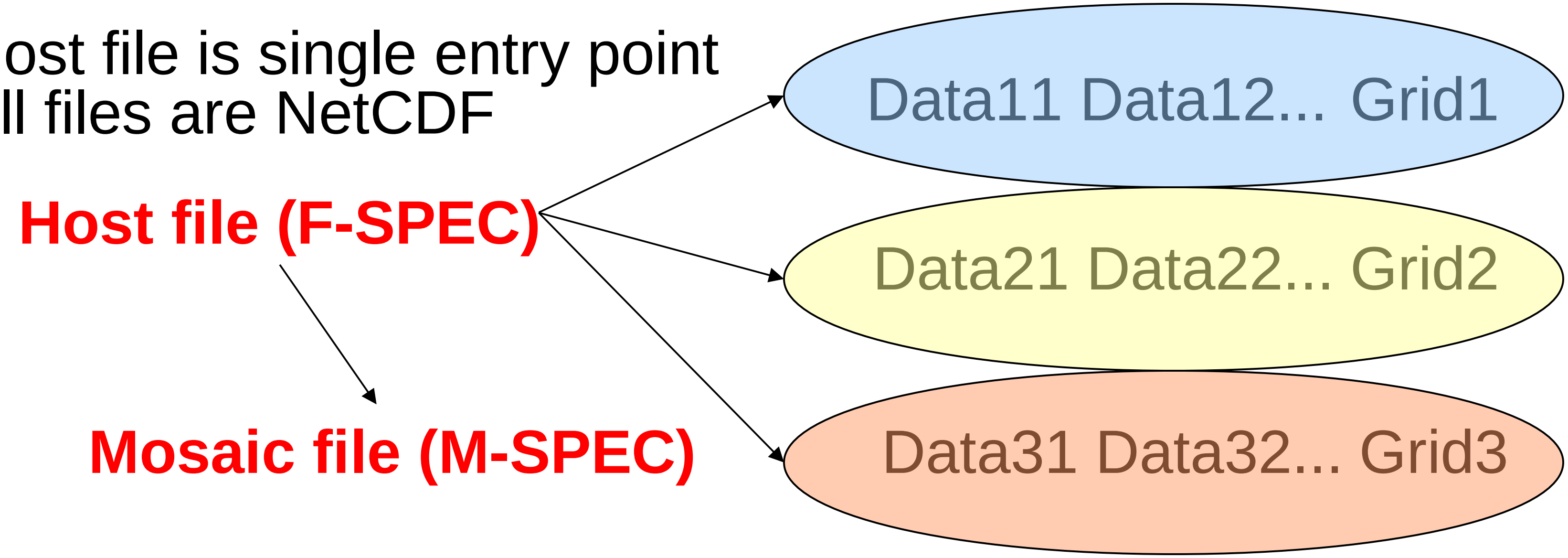
regularity

Geodesic grid ~ Voronoi mesh obtained from an unstructured grid

CF extension proposal to allow variable, time, and spatial aggregation submitted

- Different variables stored in different files
  - Time slices of a variables stored in different files
    - Spatial subsets (tiles) of a variable stored in different files

Host file is single entry point
All files are NetCDF



Host file (F-SPEC)

Mosaic file (M-SPEC)

Data11 Data12... Grid1

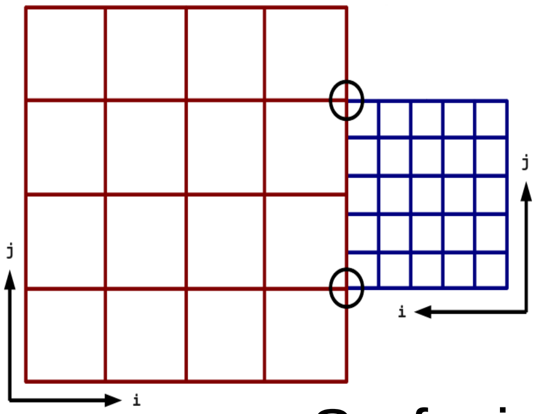
Data21 Data22... Grid2

Data31 Data32... Grid3

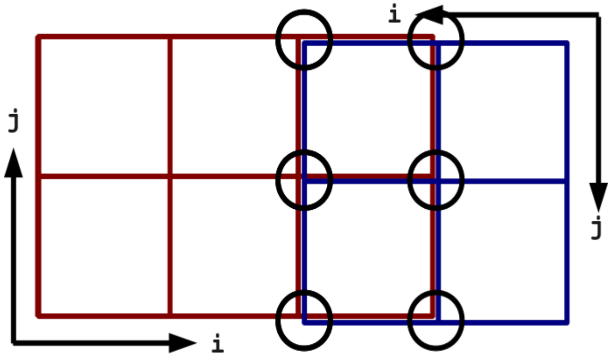
https://ice.txcorp.com/trac/modave/wiki/CFProposalGridspec

M-SPEC: Mosaic file describes the grid connectivity in index space

- GRIDSPEC developed by GFDL group
- Syntax expresses mapping of index ranges on one tile to index ranges on neighbor tile
  - e.g. “1:3 4:4 | 0:5 5:5”, “0:3 2:2 | 2:0 1:2”
  - C style indexing, 0-based, end index is inclusive
  - Tiles can have different resolution
  - Tiles can overlap



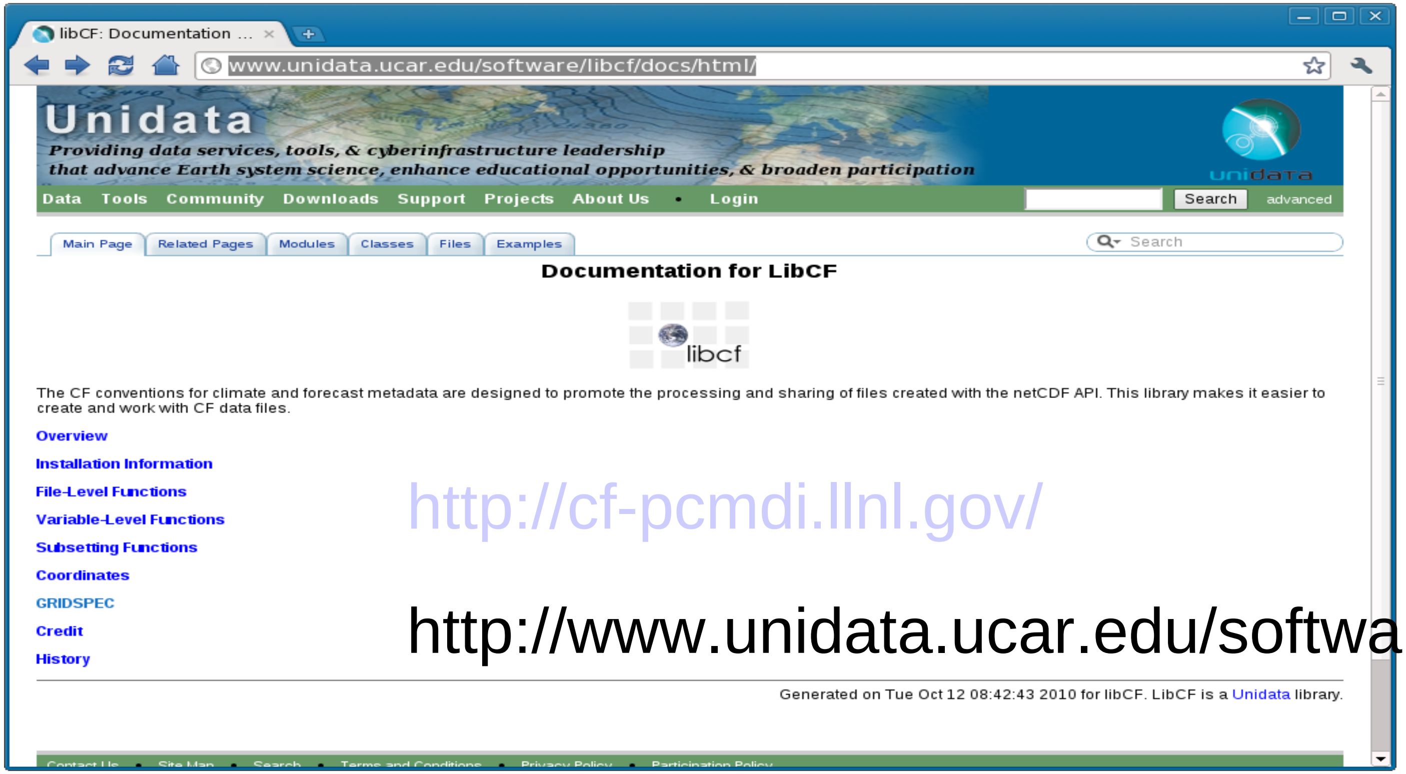
Surfacial



Volumetric

LibCF is an API implementing the CF conventions

- Developed at UCAR to facilitate CF compliance
- Supports F-SPEC (file aggregation) and M-SPEC (mosaic aggregation)


libCF: Documentation ...
www.unidata.ucar.edu/software/libcf/docs/html/
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Documentation for LibCF

The CF conventions for climate and forecast metadata are designed to promote the processing and sharing of files created with the netCDF API. This library makes it easier to create and work with CF data files.

Overview

Installation Information

File-Level Functions

Variable-Level Functions

Subsetting Functions

Coordinates

GRIDSPEC

Credit

History

Generated on Tue Oct 12 08:42:43 2010 for libCF. LibCF is a Unidata library.

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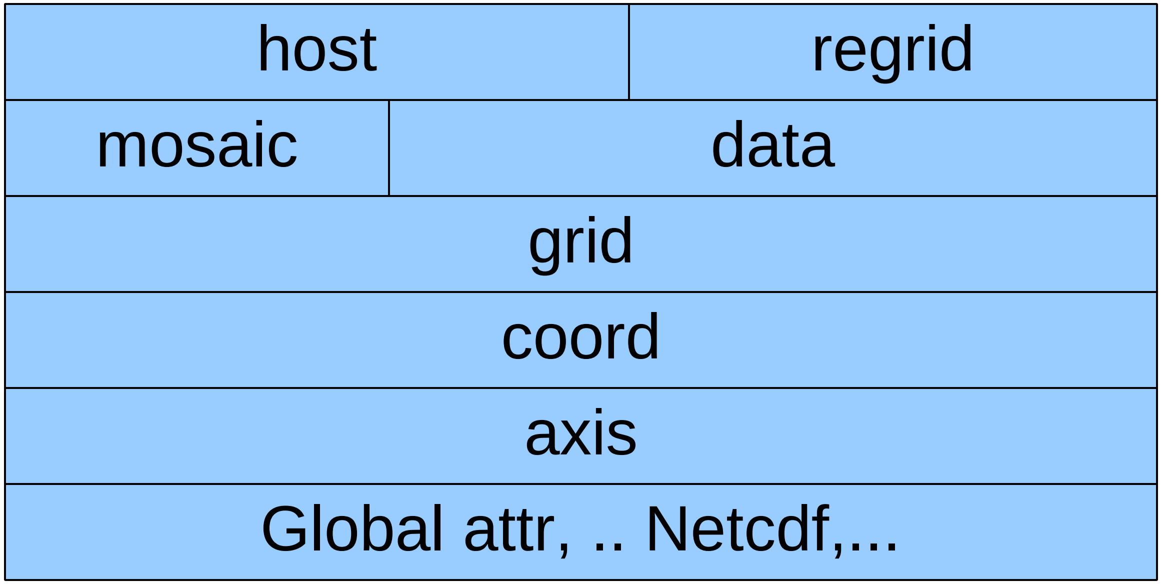
http://cf-pcmdi.llnl.gov/

http://www.unidata.ucar.edu/software/libcf/docs/

LibCF/GRIDSPEC API uses a layered approach to represent coordinates, grids, data, mosaic, and host

Each object only depends on objects below

Users can enter the API at any level.



host | regrid

mosaic | data

grid

coord

axis

Global attr, .. Netcdf,...

LibCF API facilitates language interoperability

- Code written in C follows NetCDF's calling conventions

- Extensible to other languages (arguments are primitive types). Make it easy to call from Python, Ferret, Fortran, NCL, ...

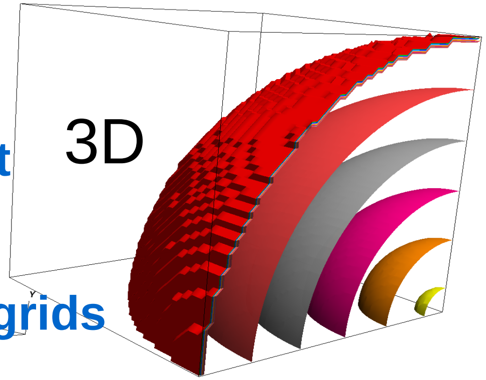
- Uses uuid (coordinates_id, data_id) to track a unified data set (grid, data, mosaic, host)

Integer ID maps to object in memory

- Define, write and free
  - `nccf_def_XXXX(..., &id); // constructor`
  - `nccf_put_XXXX(ncid, id); // write to file`
  - `nccf_free_XXXX(id);      // destructor`

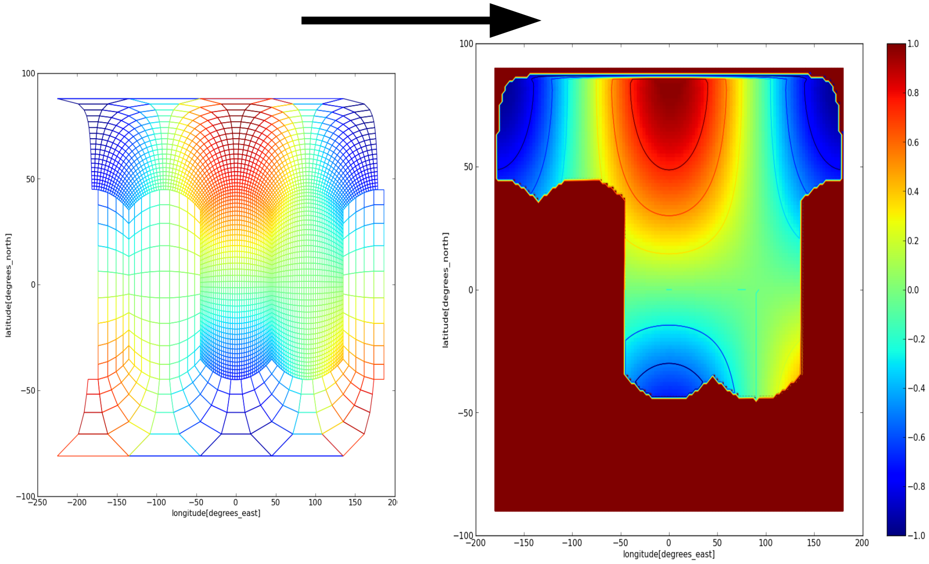
- Define from file
  - `nccf_def_XXXX_from_file(filename,..., &id);`

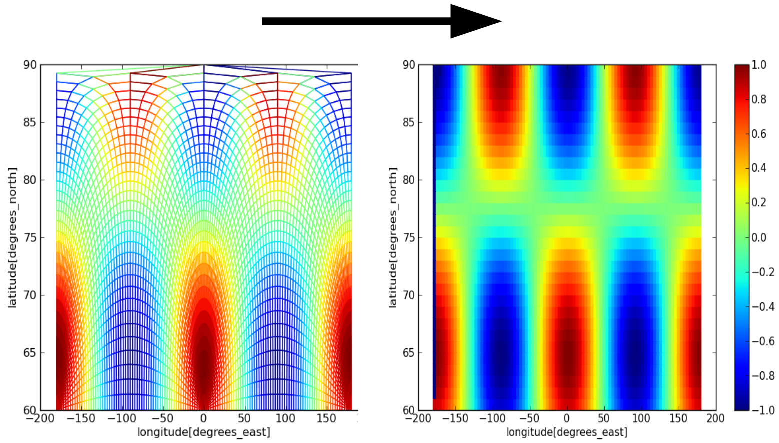
Linear regridding/interpolation i



- N-dimensional, linear interpolation only at this point
  - Straightforward to parallelize
- Pseudo-Newton search of position in index space
  - Only one iteration required for uniform, rectilinear grids
- Line search to improve convergence
- Use previous index location as initial guess when regridding from structured to structured grid

3 tiles of cubed sphere to lon-lat

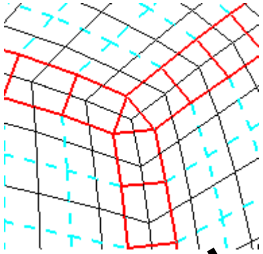




Tripolar to lon-lat

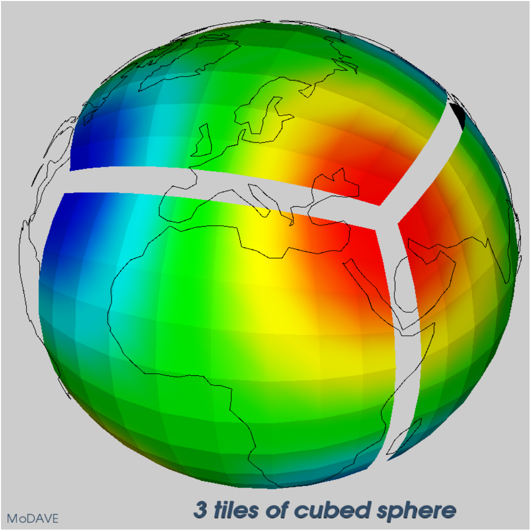
Use case for mosaic connectivity: generate the seam grid to fill gaps

The Climate Data Analysis Tools (CDAT)
opens the host and constructs the seam grids



Cell centered data
not using mosaic

Generating seam
and corner grids



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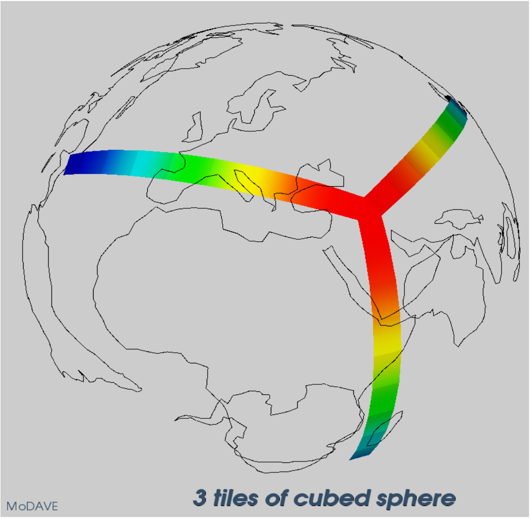

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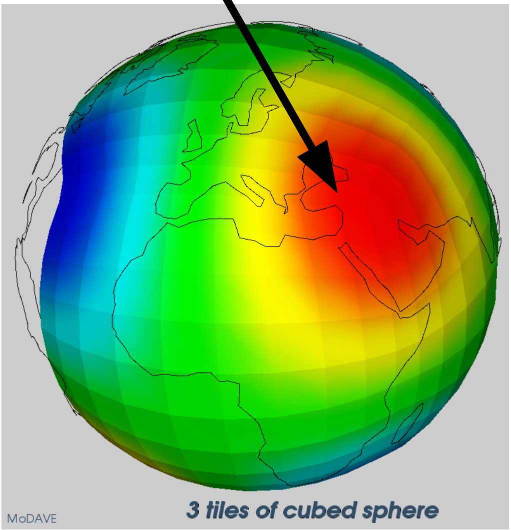
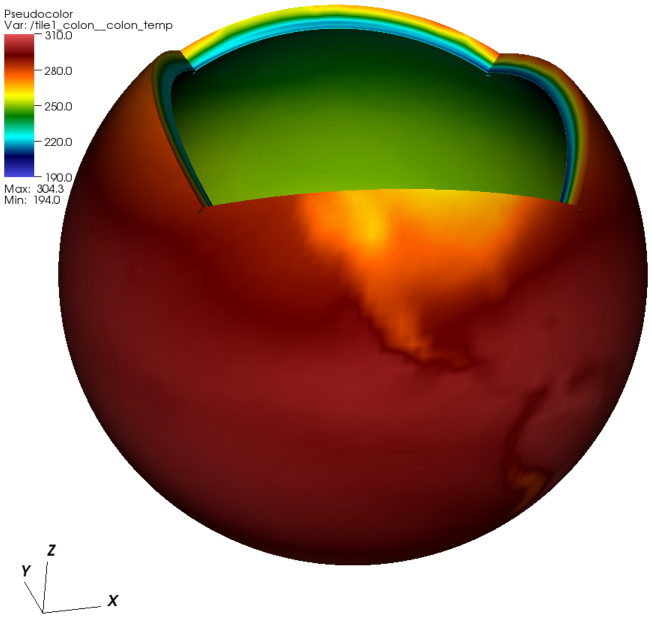
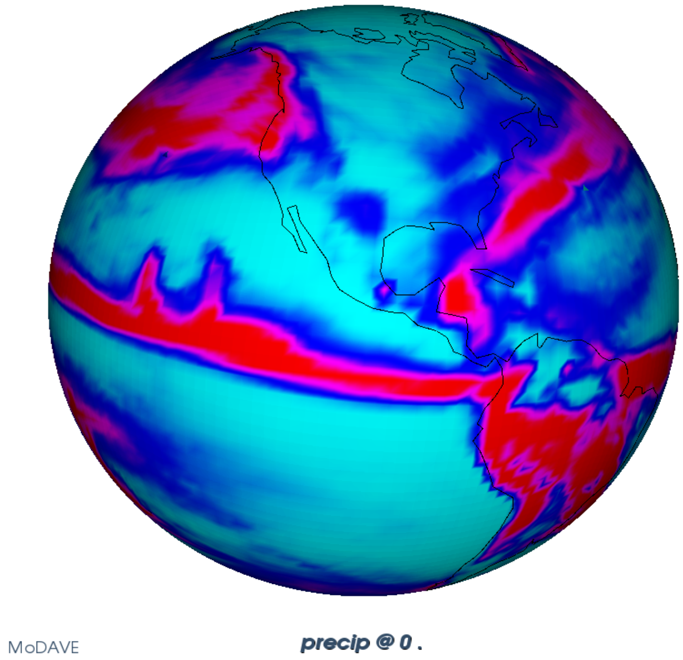


No visible grid boundaries when adding seam grids

- GFDL CM2.1 air temperature and precipitation data from the finite volume dynamic core (FV) [Lin '04]





Summary

- Mosaic grids combine the advantages of structured grids (in terms of efficiency) and unstructured grids (in terms of regular cell sizes)
- Proposal submitted to CF committee to add support for mosaics.
- LibCF has a mosaic compliant implementation
  - Dimensional agnostic (1D, 2D, 3D,...)
  - Can also do variable and time aggregation (would require another talk)
  - We can help getting started...

Open issues

- Field staggering (e.g. C and D Arakawa) not included in the CF extension proposal. CF assumes fields are nodal by default.
- Can one use cell_methods for curvilinear grids?
  - Different possibilities
    - supergrid: union of all staggered grids. Leads to strides in memory.
    - rely on the dimensions of the data. Dangerous: would not be able to discriminate between north-east and south-east face centered data.
    - new netCDF attribute, e.g. cell_offset = [-1, 0, 0] to indicate location of data on west cell face.
    - dual grids: define multiple grids, each slightly offset one from another.

Thanks for your attention!